

Rocky Mountain Research Station Science You Can Use **Bulletin**



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Hitting the Target Plant: Guiding Principles for Post-disturbance Reforestation in a Changing Climate

After severe wildfire or drought has killed trees, land managers are left with a burning question: What next? Should affected areas be left to regenerate on their own, or should they be replanted? If so, what species should be planted, when, and how? What steps can be taken to make sure reforestation and restoration efforts don't end with dead plants and wasted resources?

Managers and scientists have known for a long time that reforestation can have many ecological, economic, and cultural benefits. Planted trees sequester carbon, bolster biodiversity, yield forest products, support

ecosystem services, and provide wildlife habitat. Unsurprisingly, interest in reforestation continues to grow at the national and international levels. At the same time, the increasing frequency and severity of wildfires, drought, and other disturbances are creating new needs and opportunities to strengthen reforestation efforts.

But reforestation isn't as simple as planting trees. To spawn a future resilient forest means planting the right trees, in the right place, at the right time—or it could mean not planting at all. These efforts become



Douglas-fir seedlings growing in containers at the Coeur d'Alene Nursery, Idaho Panhandle National Forests, in 2021. USDA Forest Service photo by Kas Dumroese.

even more complicated in the context of a changing climate. Species that previously did well in a particular area may not be as successful in that location in the future, and warmer and drier conditions often make it more difficult for seedlings to establish and thrive.

Thankfully, Rocky Mountain Research Station's Kas Dumroese, Senior Research Plant Physiologist and National Nursery Specialist, and Jeremy Pinto, Research Plant Physiologist and Tribal Nursery Specialist, and their colleagues have refined and advocated for a guiding framework built on a body of research and close collaboration with forest and nursery managers. This framework can inform best practices for reforestation—now and into the future.

Shades of Green

Applying scientific inquiry to reforestation isn't new; scientists and land managers have been collaborating on this topic for more than a century.

The first Forest Service nursery opened in 1902 to provide seedlings for soil stabilization and watershed protection after severe fires. In the second half of the 20th century, as these nurseries proliferated, their focus shifted to providing seedlings for reforestation after timber harvest. More recently, demand has grown for species needed to restore degraded areas, enhance sensitive habitats, and support resistance to pests.

Since the beginning, these nurseries have also been leaders in research to improve nursery production techniques. Early on, foresters noticed that while some seedlings thrived, other planting efforts were less successful than they'd hoped. Scientists responded by asking fundamental questions about what seedlings were appropriate for certain areas and what could be done to bolster seedling success—in other words, as Dumroese says, "How far can we move it and how can we improve it?" By the 1910s, Forest Service scientists had begun to publish foundational science



Contract tree planters with some of the 530,500 seedlings that would be planted across 2,536 acres in the Lolo National Forest in Montana. Courtesy photo by Dave Gardner, Creative/National Forest Foundation.

Summary

Managers and scientists have long known that reforestation has many ecological, economic, and cultural benefits. But reforestation isn't as simple as planting trees. It means planting the right trees, in the right place, at the right time—or it may mean not planting at all.

Rocky Mountain Research Station senior scientist Kas Dumroese focuses on applying science to reforestation through a holistic framework called the Target Plant Concept. The Target Plant Concept is intended to help managers plan reforestation projects, coordinate with nursery managers, and ultimately choose plants and techniques that are best suited for management objectives. Jeremy Pinto, a Rocky Mountain Research Station scientist and Tribal Nursery Specialist, further digs into the scientific basis of the Target Plant Concept by exploring the complex connections among seed sources, nursery practices, quantifiable seedling characteristics, and postplanting growth and survival.

Climate change is creating a need for new strategies for reforestation and restoration. A new climate-informed approach focused on building resilience to future conditions is challenging conventional wisdom about seedling selection.



on these topics that stimulated global research on seedling quality and that continue to inform seedling production and planting today.

Since then, the science has continued to evolve to understand the complex interactions of seedling genetics, seedling quality, nursery propagation techniques, conditions at the outplanting site, outplanting techniques, and more. As planting efforts have expanded from reforestation to restoration of degraded lands, scientists have also had to consider the role of changing disturbance regimes and climate.

Dumroese emphasizes that there's no one-size-fits-all approach to reforestation and restoration; everything is a shade of gray (or perhaps, green) depending

on the ecosystem, project objectives, and available resources. But some key questions and guiding principles can help managers as they seek approaches with the greatest likelihood of success. "Reforestation spans many disciplines, and the scope of this research is expanding. To really provide the applied benefits to nursery managers and field professionals, research collaborations are changing. Together we can explore new and intriguing questions, work to address issues, and share the latest information with those who need it," says Dumroese.

To Plant or Not To Plant

The first question to answer is whether planting is appropriate at a given site or whether natural regeneration is a better option. On the one hand,



Contract tree planters planting whitebark pine seedlings on the Flathead National Forest, Montana in 2020. USDA Forest Service photo by Erika Williams.

natural regeneration has some clear benefits—it is less expensive, site preparation may not be needed, seeds are of local origin, and it can allow for the concurrent recovery of early successional ecosystems, such as shrubfields.

On the other hand, natural regeneration may not be fast enough to meet policy and law mandates or ecological objectives. It can also be limited by a number of factors, such as climate change, invasive plants, changes in land use, or unfavorable fire regimes. In the case of particularly large, severe disturbances such as wildfires, remaining seed sources may simply be too far away to support effective natural regeneration.

Planting can also support specific management objectives, such as increasing carbon sequestration,

timber production, or even the introduction of native species developed for pest resistance. Both approaches, Dumroese emphasizes, require post-establishment tending to meet desired objectives successfully.

As climate change brings new weather and fire patterns, some old “rules of thumb” no longer apply, and managers need to use new science and tactics to determine when and where to plant for the most success. Joe Sherlock, Forest Service Pacific Southwest Regional Silviculturist, has a wealth of experience with planting after wildfire in California, where increases in wildfire size and severity have led to huge areas of land in need of planting.

To choose where to plant, Sherlock focuses first on the site’s productivity. “We have to give these trees a chance to grow rapidly,” Sherlock says, “so they can become big enough to protect themselves from fire, competing vegetation, and other disturbances.” However, choosing a site with high productivity isn’t enough to make sure seedlings have a chance to grow. Managers need to control vegetation that competes with the seedlings for water and to remove the buildup of fuels that can bring fire back to the area while the trees are too small to survive.

The Target Plant Concept

If planting is determined to be appropriate, then the next step is to decide what to plant. Choosing the wrong species or type of plant material for the situation often results in dead plants and wasted resources.

Much of Dumroese’s research is focused on solving this problem through an approach called the Target Plant Concept. This approach was developed by nursery specialists following a “Target Seedling Symposium” held in Oregon in 1990. The Target Plant Concept’s key tenet is fitness for purpose—a plant should be cultured specifically to grow and survive for a particular planting approach, given the characteristics of a particular site. This approach requires a close partnership between the nurseries that grow seedlings and the managers who plant them.

What about natural regeneration? What we know about ponderosa pine following fire

Rocky Mountain Research Station scientists and collaborating scientists are exploring the factors that drive natural regeneration of ponderosa pine after high-severity wildland fire.

Because ponderosa pine seeds are dispersed over relatively short distances—generally only 150 feet to 200 feet—scientists theorized that ponderosa pine would be slow to regenerate in large, severely burned patches far from seed sources.

Their findings suggest that two primary environmental “filters” determine natural regeneration success. The distance from seed sources plays an important role. But even with an available seed source, climate may limit regeneration. Regenerating ponderosa pine seedlings were less abundant on warmer, drier sites at lower elevations as compared to higher elevation, wetter sites.

These results point to the limitations of relying on natural regeneration of ponderosa pine and suggest that, in the absence of planting, severely burned patches may convert from ponderosa pine to grasslands or other forest types. They also indicate that planting efforts are more likely to succeed in cooler, wetter locations, or when seedlings are placed in microsites that support these conditions, such as near downed logs or other vegetation.

[Read more in a recent Science You Can Use Bulletin 'Resilience Test: Can Ponderosa Pine Bounce Back After High-Severity Fire?'](#)



“The Target Plant Concept provides a broad outline that can be implemented in many ways,” Dumroese explains. “It can, and should, be adapted to unique circumstances or objectives—and this flexibility will become increasingly important as restoration is needed on harsher sites and climate change mitigation measures may be needed.”

The Target Plant Concept guides users through a series of key considerations that can help them choose the best plant material and a strategy more likely to yield a regenerating site.

1. Project objectives. The overall project goals have a large impact on seedling selection. For example, a project that seeks to regenerate timber supply for future harvest may call for seedlings of a commercially valuable species that have characteristics associated with rapid growth and high wood quality. A project with watershed protection goals could call for noncommercial riparian trees and shrubs. Postfire stabilization-focused projects may call for seeding native grasses and forbs with an emphasis on reducing erosion and supporting pollinators, followed by outplanting tree seedlings.

2. Type of plant material. Species selection and project characteristics will help determine what stocktype (type of plant material, including the size, shape, and age of seedling) is most appropriate. Using seeds rather than seedlings is often less expensive—but it is more appropriate for grasses and shrubs, offers less density control than planting seedlings, and can be less effective due to weather and seed predation. Seedlings grown in containers with soilless media, seedlings grown in fields (bareroot), and plants grown from cuttings all have various pros and cons. For example, container seedlings can be more tolerant during shipping because their roots are protected with media, but they are usually more expensive than bareroot seedlings. Both container and bareroot seedlings are also available in a variety of shapes and sizes. Larger seedlings tend to have an advantage on sites with competition from other vegetation, while seedlings with longer root systems may fare better when soil moisture is limiting. Price is often an important factor when deciding on a stocktype.

3. Genetics. Plants are genetically adapted to local environmental conditions, so seedlings from the geographic area where they will be outplanted generally tend to have better outcomes. This isn’t the only genetic consideration, though—genetic diversity matters, too. Maintaining genetic diversity is desirable because it provides resilience to future change. For dioecious species (plants that are either male or female), sexual diversity is also necessary to ensure plants, especially rooted cuttings, can continue to reproduce and regenerate after planting.

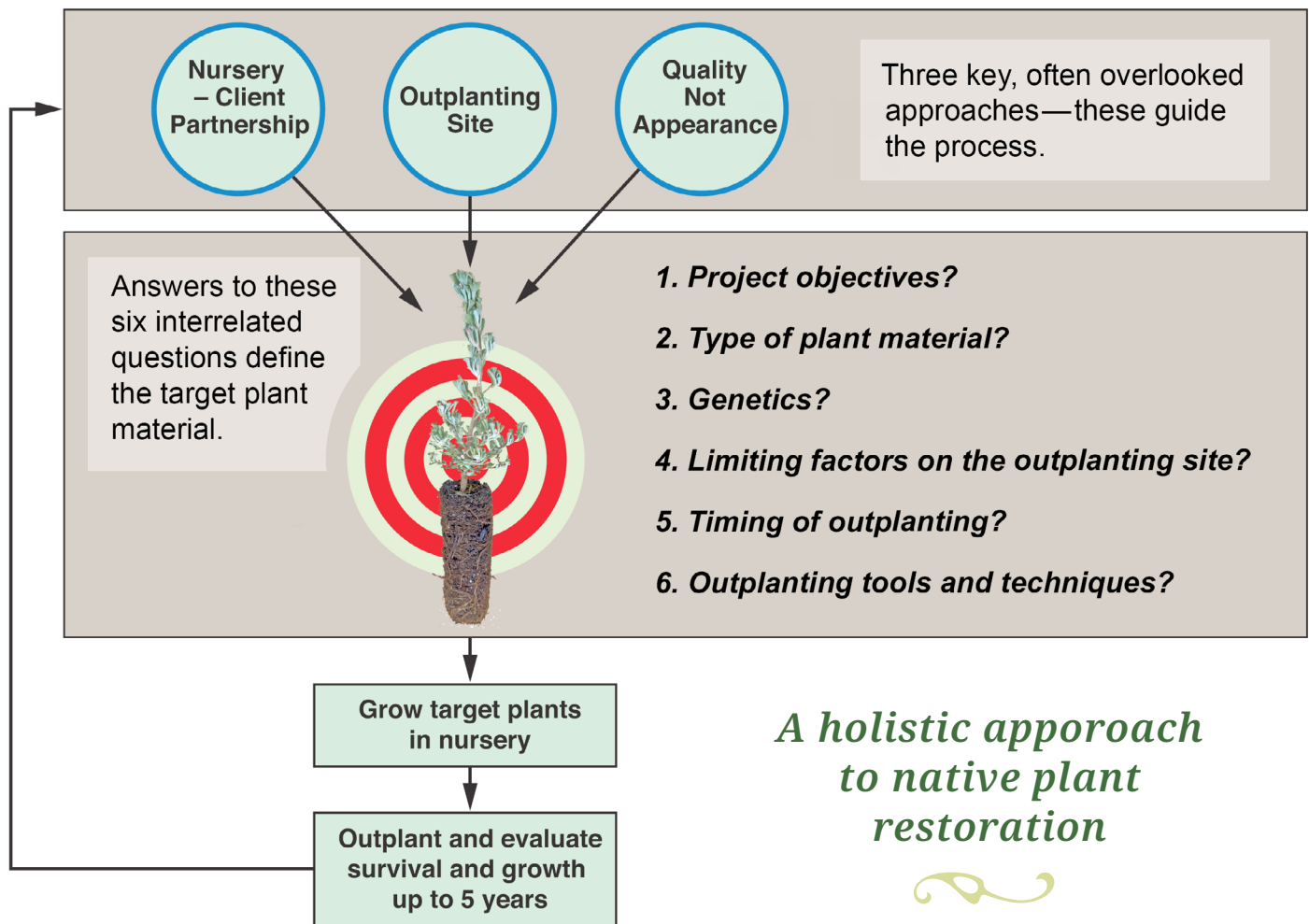
4. Limiting factors on the outplanting site. It is especially important to evaluate what conditions at a site are most limiting to plant growth and survival so that seedlings and techniques best suited to mitigating these limitations can be selected. Often, the greatest limiting factor is soil moisture. Other factors can also limit growth, including temperature, grazing, wind speed, competition from other species, and/or the resources and capacity of the organization doing the planting. An evaluation of limiting factors also needs to consider the recent history of the site, such as harvest or fire, as well as how conditions may change in the future. For example, severe wildfire may result in changes in soil pH or losses in symbiotic fungi that can create unexpected limitations.

5. Timing of outplanting. Outplanting should be scheduled when environmental conditions on the site are most favorable to plant growth and survival—usually

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The Target Plant Concept



at the onset of a sustained period of ideal soil moisture and temperature. In most of the United States, this often means planting dormant stock in the spring. In other parts of the country, it can mean planting during the winter months or summer monsoons. The timing of planting dictates how a nursery will need to treat and handle the stock; for example, hardening treatments can help improve the survival of seedlings intended for fall planting.

6. *Outplanting tools and techniques.* There is no one right way to plant, but the planting method should be a good match with both the stocktype and the project site. Important factors to consider include: site preparation, such as removing existing vegetation; the spacing and

exact locations of plantings (for example, in favorable microsites, such as shaded areas near downed logs); and any treatments that are necessary at planting time, such as protective structures to minimize herbivory.

Finally, another key tenet of the Target Plant Concept is adaptive management. Figuring out the right match between plants and projects is an ongoing process, and postplanting monitoring and surveys are a critical part of making future efforts more effective and efficient.

Getting to the Root of Nursery Stock Survival

These interrelated target plant concepts provide a holistic framework to help managers plan reforestation

and restoration projects and coordinate with nursery managers. But how, exactly, do these ideas translate into suitable seedlings? What measurable seedling characteristics and nursery practices create the best chance of survival for a particular site, at a certain time, given specific objectives?

Jeremy Pinto is focused on improving the scientific approach to evaluating seedling quality in the context of the Target Plant Concept. Through controlled trials, Pinto's work shows how seedling cultivation, site preparation, and other factors can mitigate outplanting site limitations such as drought conditions and competing vegetation. He focuses on the complex connections between seed sources, nursery practices, quantifiable seedling characteristics (such as root size and morphology, photosynthesis rates, and water movement), and postplanting growth and survival.

Cultivation practices determine seedling characteristics. By adjusting growing medium composition, temperature, irrigation, fertilizing, and lighting, nursery managers can directly influence the attributes that will allow a seedling to thrive under specific site conditions.

One recent study by Pinto and colleagues, for example, found that limiting nursery irrigation of aspen seedlings could induce greater rates of photosynthesis and water use in seedlings, which potentially could promote better survival on drought-prone planting sites.

Another study focused on the interplay of container size and vegetative competition for seedling growth and survival for Douglas-fir and western larch. Results indicated that the benefits of a larger container size seemed to plateau beyond 8 cubic inches. They also demonstrated the importance of controlling competing vegetation regardless of the stocktype, especially for western larch.

"In many cases, we've correlated morphological and some physiological seedling attributes with survival and growth, but our knowledge is still somewhat



Jeremy Pinto measuring the physiological response of aspen seedlings to nursery treatments in 2016. USDA Forest Service photo by Kas Dumroese.

limited in this field," says Pinto. "Our research is working towards peeling back the layers of onion, so to speak, of what nursery cultivation does to the morphophysiological functioning of a seedling. The tools we use to measure these 'layers' are improving, and what we learn will improve targeted nursery culturing techniques for better outplanting success. The scientific process is a critical link to the Target Plant Concept. It helps us continuously improve our efforts."

Collaboration with nursery managers is also critical to putting these concepts into practice. Through his role as the Tribal Nursery Specialist for the National Center for Reforestation, Nurseries, and Genetic Resources, Pinto works directly with Tribal nurseries to inform

their efforts to grow seedlings that will be the best fit for their restoration projects and objectives.

Jeremy Ojua, Nursery Manager for the Native Plant Materials Program of the Confederated Tribes of Grand Ronde (CTGR), works with Pinto and Dumroese to implement the Target Plant Concept in Oregon. “One of the ways the Confederated Tribes of Grand Ronde is utilizing the Target Plant Concept on its restoration sites is by collecting

cuttings, divisions, roots, and seeds of native plants directly from the restoration site or close by and using them to grow new plants in the nursery,” says Ojua. “Then, managers use those plants for the restoration plantings, bringing them back to the site from which they originated.”

Through CTGR’s Native Plant Materials Program, Ojua grows many plants in the nursery for their cultural significance—whether as

a food, a medicine, or materials used in the making of tools and in basketry—to have more of these plants available for the community to gather and use.

Rethinking Reforestation in a Changing Climate

Climate change has added even more urgency to Dumroese and Pinto’s work. As climate change drives more frequent and severe fire and drought, the scale of reforestation needs is increasing.

Native Plant Materials Program of the Confederated Tribes of Grand Ronde

Tribal Nursery Supervisor Jeremy Ojua works with the Native Plant Materials Program of the Confederated Tribes of Grand Ronde (CTGR) to engage Tribal youth, staff, and community members in growing and planting culturally significant plants. In 2018, the CTGR, in collaboration with the Oregon Parks and Recreation Department and the Institute for Applied Ecology, hosted a planting day celebration at a restoration site along the Willamette River in Champoege Park. During the celebration, the community planted camas, yampah, and many other

culturally significant native species. The CTGR Cultural Resources Department also provided opportunities to learn about traditional practices, including an earthen oven that was used to cook and serve food to participants. Additional planting and hand-weeding parties continue to take place each year.

The CTGR Youth Education Department also has eight raised garden beds for growing traditional food species. These

beds are used for education during afterschool programs for Tribal students. The construction of the beds was a collaborative project between CTGR’s departments of Natural Resources, Youth Education, and Maintenance and Facilities, and the nonprofit Marion Polk Food Share. Sharing resources, these groups built and maintain the garden beds on the grounds of the Youth Education Department.

Camas (Camassia leichtlinii) growing in a raised bed at the Confederated Tribes of Grand Ronde nursery. Courtesy photo by Jeremy Ojua, Confederated Tribes of Grand Ronde.

“Our research is working towards peeling back the layers of onion, so to speak, of what nursery cultivation does to the morphophysiological functioning of a seedling. The tools we use to measure these ‘layers’ are improving, and what we learn will improve targeted nursery culturing techniques for better outplanting success.” – Jeremy Pinto





Confederated Tribes of Grand Ronde Social Services staff visiting the nursery to learn about camas and harvest the bulbs that would later be planted at a restoration site at Champoeg Park, Oregon. Courtesy photo by Jeremy Ojua, Confederated Tribes of Grand Ronde.

At the same time, climate change makes it even more difficult to rebuild forests that can withstand future conditions.

Over the last decade, Dumroese and Pinto have explored how reforestation and restoration can be adapted to build resilience in the face of climate change. This new climate-informed approach is challenging conventional wisdom and reframing how we think about seedling selection.

Functional restoration is one management strategy that can help with mitigation and adaptation to climate impacts. Rather than trying to restore ecosystems to the species compositions from historical reference points, functional restoration focuses on what forests provide—such as wildlife habitat, improved water quality, forest products, or cultural resources—and ultimately seeks to restore and protect ecosystem health.

In practice, this approach may mean favoring species or genotypes that will do better under anticipated future conditions or seeking to maintain genetic diversity that will facilitate future adaptation.

For example, Rocky Mountain Research Station's Anna Schoettle, Research Plant Ecophysiologicalist, and colleagues have worked closely with park rangers to develop [a proactive approach for limber pine conservation](#) in Rocky Mountain National Park (Colorado). Limber pine is threatened by the combined impacts of climate change, mountain pine beetle, and the invasive white pine blister rust pathogen. Components of the strategy

ADAPTIVE SILVICULTURE FOR CLIMATE CHANGE

Rocky Mountain Research Station scientists are partners in the [Adaptive Silviculture for Climate Change Network](#), a collaborative effort to establish a series of long-term experimental silvicultural trials across a network of different forest ecosystem types, from Montana to Georgia.

These experiments are intended to evaluate management options designed to enhance forests' ability to respond to a changing climate—including planting, alongside other treatment options such as thinning.

These treatments can be divided into three categories:

- Resistance treatments are designed to defend the forest against anticipated change and maintain relatively unchanged conditions. Treatments may be focused on maintaining the current species composition.
- Resilience treatments are designed to allow some change, with an eventual return to reference conditions. An example of a resilience treatment is planting native future-adapted species, such as those with particular resistance to drought, and preferential thinning to shift species composition toward more resilient species.
- Transition treatments facilitate change and encourage an adaptive response. Transition treatments may include planting both native and novel future-adapted species and removing species expected to fare poorly under future conditions.

The network's trials are still in relatively early phases, but during the coming years, results are expected to help managers choose treatments and planting strategies that align with management approaches to climate change.



include planting limber pines to offset future mortality, carefully managing genetic diversity through planting to maintain resistance to blister rust, and developing a seed bank of resistant genotypes to supply future planting efforts.

In some areas, climate is expected to change faster than trees can adapt or migrate. Foresters may adjust which species, or populations within a species, they are planting in certain areas—or even move species outside their historical range—to allow healthy forest to persist. This is, in some ways, a new way of thinking for resource managers, who in the past have focused on using seedlings from local sources to increase success.

Forest Service scientists are developing new tools to help match the right plants with the right locations in light of climate change. At the Pacific Northwest Research Station, scientists have developed the [Seedlot Selection Tool](#), which can help match seedlots (seed collections from a known origin) with outplanting sites based on climatic information. The [Climate Smart Restoration Tool](#), developed at the Rocky Mountain Research Station, can offer climate-informed seed zone recommendations for sagebrush and grassland ecosystems.

Key Findings and Management Applications

- Natural regeneration and planting can be effective reforestation approaches after wildfire, drought, or harvesting, depending on the specific circumstances and objectives— and both require post-establishment care.
- If planting is appropriate, managers also need to select the right plants to ensure project success. The Target Plant Concept provides a holistic, integrated framework to find the right match between project objectives, site characteristics, outplanting tools and techniques, and plants.
- Appropriate seedling cultivation and site preparation can help mitigate outplanting site limitations such as drought conditions and competing vegetation.
- Innovative approaches to reforestation and restoration can adapt to and help build resilience in the face of climate change through, for example, favoring species or genotypes that are expected to fare better under future conditions.

Forest Service managers and scientists, including Dumroese, are also finalizing a national strategy for reforestation on Forest Service lands to address the agency's reforestation needs and prepare for future scenarios.

Finally, Dumroese notes, “Implementing these new approaches must be part of a holistic framework that emphasizes long-term monitoring and adjusting management approaches as we see what works and what doesn't. The end result is that restoration work to maintain ecosystem function is done in the most efficient and economic ways possible.”

Further Reading

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Scientists and Manager Profiles

The following individuals were instrumental in the creation of this Bulletin:



Kas Dumroese is a Senior Research Plant Physiologist and National Nursery Specialist with the USDA Forest Service's Rocky Mountain Research Station in Moscow, Idaho. He earned his M.S. in Forest Resources and Ph.D. in forestry from the University of Idaho. He is currently focused on providing the National Forest System with the science foundation for a National Reforestation Strategy, understanding the long-term processes of tree root system architecture in response to nursery practices and on-going mechanical stresses, evaluating biochar to improve nursery efficiencies, and describing long-term effects on carbon and nitrogen pools under different land management and silviculture scenarios. He also serves as Director of the Western Center for Native Plant Conservation and Restoration Science.



Jeremy Pinto is a Research Plant Physiologist and Tribal Nursery Specialist with the USDA Forest Service's Rocky Mountain Research Station in Moscow, Idaho. He earned his M.S. in forest resources and Ph.D. in natural resources from the University of Idaho. His current research includes examining and improving native plant nursery cultural practices, investigating subsequent consequences of cultural practices on seedling physiology, and studying the biophysical site limitations of outplanting.



Joe Sherlock is the Regional Silviculturist for the USDA Forest Service's Pacific Southwest Region in Vallejo, California. His continuing pursuit of biological and physical science competency supports the development of effective silvicultural practices in a region that offers a complex social and physical environment.



Jeremy Ojua is the Native Plant Nursery Supervisor at the Natural Resources Department for the Confederated Tribes of Grand Ronde. Prior to supervising nursery operations, Jeremy worked for 13 years as a Wildland Firefighter and Silviculture Technician for the Tribes' wildland fire program. He helped to fight wildfires across the country and to maintain healthy forests on the Tribes' reservation lands.



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About the Science You Can Use Bulletin

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